The Importance of Bedside Ultrasonography in Confirming the Location of Endotracheal Tube

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ABSTRACT

Objective. Endotracheal intubation may be associated with lethal complications when not applied in appropriate manner. In this study, we aimed to examine the efficiency of transcricoid and pulmonary ultrasonography in confirming the position of the tube in comparison with classical methods.
Methods. This study was carried out between 2016 and 2017 in Turkey and was registered in Clinical Trials under number NCT03081221. The location of the tube was confirmed using methods such as monitoring the vocal cords during direct laryngoscopy, condensation on endotracheal tube during respiration, epigastric-pulmonary auscultation, radiography and capnometry. After that, the transcricoid and pulmonary ultrasonography were implemented by the blinded pediatric emergency care specialist.
Results. 64 cases who needed advanced airway requirements were involved in this study. The double-line appearance could not be obtained from one patient only when using transcricoid ultrasonography, but the bilateral pleural shift movement was observed among all the cases by using pulmonary ultrasonography (sensitive: 98%-100%).
Conclusion. The determination of endoesophageal, endotracheal and endobronchial intubations can be easily made by using transcricoid and pulmonary ultrasonography. The use of ultrasonography may significantly contribute to critical airway management as fast, accurate and on time.

Keywords: Endobronchial intubation, Endotracheal intubation, Ultrasonography.

INTRODUCTION

Endotracheal intubation is applied under emergency or elective conditions in order to protect or secure the airway of critical patients (1). The frequency of esophageal intubation (EI) in emergency units ranges between 6 and 16% (1, 2). The inaccurate location, especially in intubations applied under emergency conditions, may result in degradation of oxygenation in vital organs and loss of critical hours during confirmation process. Classical confirmation methods used are vocal cord observation by using direct laryngoscopy, epigastric and pulmonary auscultation, condensation on thoracic tube, observation of the ascending and descending movements of the thorax, observing the tube on the carina line by using direct radiography, pulse-oximeter, and capnography (1, 3). The most useful method known is (except for the false results under certain circumstances) measuring the end-tidal carbon dioxide (1, 4).

In the present study, it was aimed to determine the compatibility of endotracheal tube location confirmation by using ultrasonography (USG), which is an easy, fast, reliable, and useful method utilized frequently by the emergency unit physicians during critical patient management, with classical methods.

METODS

The present study was prospectively carried out between March 2016 and June 2017 in Pediatric Emergency Rooms and PICUs (Pediatric Intensive Care Units) of Çukurova University, Turkey. The approval of ethics committee was obtained before the study (13/01/2017). The study was registered in Clinical Trials under number NCT03081221. The patients, who were brought when only the researcher was in the unit and who were in need of endotracheal intubation, were involved. All the intubations were confirmed using classical methods such as monitoring the vocal cords during direct laryngoscopy, condensation on endotracheal tube during respiration, observing the ascending and descending movements of the thorax, epigastric and pulmonary auscultation, direct radiography and capnometry. The emergency interventions on patients were executed in accordance with their clinical conditions and then, by using the Sonosite Edge USG device and high-definition 6-15 MHz planar probe, the images of transcricoid membrane were taken from the transverse and sagittal cross-sections by palpating the cricoid cartilage when the patient was in supine position. In both cross-sections, the hyper-echoic double line appearance was sought in trachea and esophagus. The double line appearance in trachea was accepted as the accurate intubation (Figure 1). Then, the same probe was used in searching for the pleural shifting movement between the 2nd and the 4th intercostal spaces in both of pulmonary sagittal cross-sections. The bilateral lung sliding was determined to be endotracheal intubation, the unilateral appearance was accepted to be endobronchial intubation and non-appearance to be the endoesophageal intubation. The implementation was performed by a pediatric emergency specialist having USG training, and the duration was recorded.

RESULTS

64 patients in total (median age of 43.89 months, IQR: 7.23-94.62), of whom 38 (58.4%) were girls, who underwent endotracheal intubation when the single researcher, who carried out the present study, was alone, were involved in this study. 15 patients were intubated under the emergency conditions while the others underwent intubation under elective conditions.

The endotracheal intubation was most frequently applied because of respiratory or cardiovascular failures (27 patients - 42.18%). The second most frequent reason was the central nervous system pressure, followed by the patients prophylactically intubated because of other reasons. Five patients were brought to the emergency unit with cardiac/respiratory arrest (Table 1).

Except for the patients brought to the emergency unit with cardiac-respiratory arrest, all the patients were sedated/ given analgesics at least once before the intubation, and fifteen patients were given paralyzing agent once. Midazolam, fentanyl, and rocuronium bromur were preferred.

In Table 2, the success rates of classical methods in confirming the endotracheal intubation are presented, whereas Table 3 shows the success rates of ultrasonography method.

After the first evaluation of patients, the double line appearance was sought in sagittal and transverse images taken using transcricoid USG, and this appearance could not be seen in one patient only (sensitiveness 98%) (Figure 2). Among all the patients, the movement was observed in trachea when the endotracheal tube was moved. This movement was confirmed with formation of color line in trachea by using the color Doppler in 54 patients (83%) (Figure 3).

Pleural shifting was observed in pulmonary USG assessments of all the patients (sensitiveness 100%). Since all of the patients were intubated without any complication, no sensitiveness value was calculated. The mean duration of completing the imaging was 38.82 sec.

Table 1. Demographic data of patients

Indication	Number of Patients (n)	Percentage (%)
Central nervous system	19	26.68
Respiratory and cardiac failure	27	42.18
Prophylactic	13	20.3
Cardiac-respiratory arrest	5	7.81
	64	100

Table 2. Classic methods used in confirming the endotracheal intubation

Classical methods used in intubation	Number of Patients (n)	Percentage (%)
Seeing the vocal cords during intubation	64	100
Observing the ascending and descending movements of thorax	64	100
Condensation on the endotracheal tube	64	100
Intubation supported by auscultation (lung, stomach)	64	100
Direct radiography	64	100
Confirmation using End-tidal Carbon Dioxide (EtCO2)	64	100

EtCO2 ,End-tidal Carbon Dioxide

Table 3. Ultrasonography (USG) results in confirming the endotracheal intubation.

Ultrasonography (USG) Results	Number of Patients (n)	Percentage (%)
Double line appearance in transcricoid USG	63 (not observed in 1 patient)	98
Absence of enlarged esophagus appearance (no double line sign)	64	100
Observing the movement in trachea when the endotracheal tube is shaken up-down	64	100
Observing the color line in the trachea in color Doppler when the endotracheal tube is shaken up and down	54	83
Presence of pleural shifting movement in pulmonary USG	64	100

USG, Ultrasonography

DISCUSSION

If the endotracheal intubation is not applied appropriately or the endoesophageal intubation is not successfully accomplished, then hypoxia, brain damage, or death may occur (5). The present study involves data corroborating that the location of tube can be determined in a short time after the intubation by using USG and that the use of USG is a reliable method in managing critical moments.

There have been USG devices in most emergency units since 1990s and they have been widely used by the emergency specialists. After the articles published between 2009 and 2012 by the Council Emergency Medicine Residency Directors, it started to play a significant role in managing critical patients (6). In a study carried out by Chenkin et al. (7) on 66 emergency medicine specialists and assistants having no USG training background, it was shown that the participants could accurately identify the location of the tube after the training on USG. Similarly, in a study carried out by Gottlieb et al. (8) on 45 emergency physicians that had just started working in this occupation, the participants worked with 150 USG-imaged new cadavers and they successfully identified the location of the tube in skinny cadavers (91% sensitivity and 96% specificity). In obese cadavers, the participants identified the location of the tube with sensitiveness of 100% and specificity of 48%. In that study, it was

Figure 1. Image of an application in this study

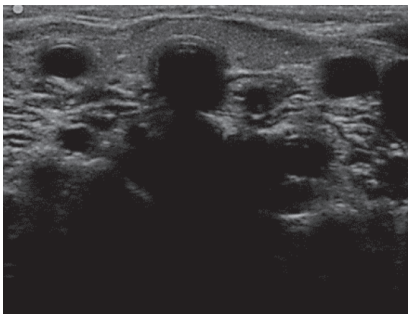

Figure 2. Double-line image in trachea in this study

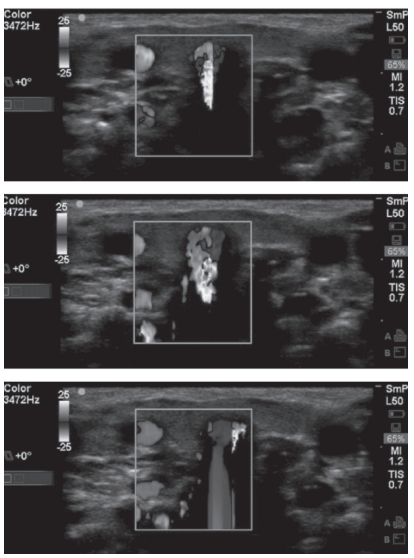

Figure 3. Color line in trachea taken using color Doppler

reported that the success rate increased together with the increasing experience of emergency physicians (8). The present study was also carried out in a unit where USG is frequently used. The images were taken by a pediatric emergency specialist having USG training background, and the accuracy of tube locations was determined at 100% sensitiveness level.

In patients with respiratory and circulatory failure, suppressed consciousness and inability to sustain airway, as well as in patients requiring airway openness to be ensured prophylactically, the endotracheal intubation performed in short time period and without any complications is a life-saving intervention (1, 9). Fifteen of the patients involved in the present study were intubated under emergency conditions. First, the location of tube was confirmed using classical methods. Classical methods used in confirming the location of tube in emergency practice and also in the present study such as monitoring the vocal cords during direct laryngoscopy, observing the condensation on endotracheal tube and ascending and descending movements of chest after the implementation of balloon/mask, and epigastric and pulmonary auscultation are clinician-dependent methods and might be affected by environmental conditions (1, 4, 10, 11). Previous studies showed that the pulmonary auscultation has 74-91% sensitiveness level and 91-100% specificity (4, 11). The tube condensation might not be observed in patients having high airway resistance or those having low pulmonary capacity. The gas content of stomach might suggest that the thoracic wall moves bilaterally, the patient may aspirate the stomach content because of the balloon mask respiration (3, 4, 9). Since the esophageal intubation might be determined earlier if the location of the tube is examined using USG, the patient would be protected from the aspiration risk (2). Similarly to the present study, Moghadam et al. (2) used classical methods and reported the USG's sensitiveness to be >90% and specificity to be 80-90%. Moreover, Pfeiffer et al. (9) compared USG to classical methods as in the present study on 22 patients, all of whom had undergone successful intubation, and reported that there was no statistically significant difference between the auscultation durations in case of USG (47.5 sec.), whereas the USG offered statistically significantly shorter period (43 sec.) when the auscultation was combined with capnography (55 sec.) ($p<0001$). We didn't record the implementation times of classical methods, but we showed that the intubation was not endoesophageal but endotracheal, and that the localization (non-endobronchial) can be showed in a short time period (38.82 sec.). In the study of Moghadam et al. (2), in which they took classic methods consisting of thoracic-epigastric auscultation, tube aspiration, direct laryngoscopy and pulse oximeter as reference as in the present study, the authors reported the sensitiveness of USG to be >90% and specificity to be 80-90%.

Even though radiography is widely used by many clinicians in determining the position of Endotracheal Tube, it is a time-consuming method exposing the patient to radiation (3). The end-tidal carbon dioxide (EtCO2) measurement is considered as the most reliable method in today's practice. Among the patients having airway obstruction, severe respiratory failure and low cardiac output during cardiopulmonary resuscitation (CPR), the EtCO2 measurement might yield false negative results, even though it might also yield false positive results because of the low carbon dioxide content of esophagus (1, 2, 4, 10). In order to perform the measurement, the ventilation by balloon-mask is required and this might cause the aspiration of stomach content among the patients in whom the necessary precautions were not taken (2, 4). The EtCO2 measurement does not allow determining the exact location of tube (1, 3, 9).

The endotracheal intubation can be confirmed by obtaining double line appearance in trachea by using USG and by showing that there is no esophageal enlargement by showing the double-line appearance in esophagus. Thus, the endoesophageal intubation can be excluded and the possible complications of endoesophageal intubation may be prevented. On the other hand, as aimed in the present study, the endotracheal and endobronchial intubations (in other words, if the tube has been placed accurately) can be distinguished by using USG, and the pulmonary defect, hypoxia-caused bradycardia and cardiac arrest, and the hypoxic brain damage that might occur in case of inaccurate placement can be prevented (5).

In the study carried out by Adi et al (12), in which they involved 107 patients (6 of which have been undergone endoesophageal intubation) and compared the capnography that is nowadays accepted as the golden standard in confirming the endotracheal intubation, the authors reported that the USG is very reliable in confirming that the tracheal tube has been placed accurately (sensitiveness: 98%, specificity: 100%.

Moreover, USG can be also used in following the location of the tube during follow-up of patients in intensive care unit (5). Since ultrasonography enables the real-time confirmation of intubation for the patients in whom intubation is very difficult, it may gain an advantage against other methods (5, 13).

There are studies in literature unlike our

study which synchronously confirm using USG during intubation. In a study carried out on 30 patients, Park et al. (14) obtained images by using transcricoid USG during the dynamic process of intubation and reported the sensitiveness value of 96.3% and specificity of 100%. Then they determined that the pleural shifting movement in both lungs has 100% sensitivity and specificity in determining if the tube is at endobronchial position (14). On the contrary to that, Tsung et al. (15) reported that the procedure might be confirmed by seeing the empty esophagus during the dynamic process of intubation. In their study 89 patients brought to the hospital during intubation, 3 minutes after intubation (the period of observing the clinical response), and 3 minutes after on-field intubation were involved and 115 ultrasound images were taken, Hoffman et al. (16) performed the confirmation by seeing the tube exceeding beyond the vocal cords, monitoring the preoxygenation and response, and using capnography. In that study, they reported the sensitiveness and specificity of confirmation using USG to be 97.8% and 90% for endotracheal intubation and 90% and 98.9% for endoesophageal intubation, and that the imaging process was accomplished in 5 seconds. In their study, in which they took direct laryngoscopy and capnography as reference and took the images of 120 patients during (dynamic) and after (static) intubation, Abbasi et al. (17) reported the sensitivity and specificity of method to be 98.1% and 100% in dynamic phase and 100% and 100% in static phase, respectively.

CONCLUSION

The present study showed that the endotracheal intubation can be confirmed by using transcricoid USG and that it can be easily determined without any complication by bilaterally observing the pleural shifting movement via pulmonary USG that there is no endobronchial intubation. More comprehensive studies involving higher number of patients, incorporating imaging dynamically performed synchronously with the intubation process, and having a blind implementer are needed.

Ethical Statement

This article does not contain any studies on human or animal subjects performed by any of the authors.

Conflict of interest

Authors declare no financial or commercial conflict of interest.

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